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Technical Paper 343

DEPARTMENT OF COMMERCE
HERBERT HOOVER, SECRETARY

BUREAU OF MINES
D. A. LYON, ACTING DIRECTOR

GEORGIA AND ALABAMA CLAYS AS FILLERS

BY

W. M. WEIGEL

DEC 16 19
UNIVERSITY OF ILLINOIS

PRICE, 10 CENTS
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Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

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By W. M. Weigel

INTRODUCTION

The white clays or kaolins of Georgia and, to a small extent, of Alabama, have been utilized in the ceramic industry for many years. Some of these deposits have supplied clay to paper manufacturers and a very few have produced clay for use in rubber compounding and the manufacture of oilcloth and paint. As many owners and operators of clay deposits are unfamiliar with the different requirements for clays to be used as fillers, and so are unable to prepare their product for the market to which it is best adapted, the Bureau of Mines, in its endeavor to increase efficiency and economy in the mineral industries, has studied the clays in question to ascertain the uses to which they could be most efficiently put. A study of the Georgia clays for ceramic use was the subject of an earlier investigation by the Bureau of Mines.[1]

The principal manufactured articles in which clay is used as a filler or coating material are paper, wall paper, rubber, paint, oilcloth, textiles, kalsomine, plaster, and matches. For these uses, the clay must be white or nearly so, and in this investigation only the white clays or sedimentary kaolins were considered.

The following figures illustrate the amount of domestic clays sold for filler purposes during 1923:[2]

Consumption of clays for fillers

Use:	Short tons
Paper filler	102, 732
Paper coating	9, 031
Rubber	15, 279
Oilcloth or linoleum	8, 165
Paint filler or extender	13, 328
Paint pigment	259
Plaster and plaster products	5, 582
Kalsomine	2, 386
Crayons (for tailors' use, etc.)	1, 009
Total	157, 771

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[1] Stull, R. T., and Bole, G. A., Washing tests of Georgia clays: Jour. Am. Cer. Soc., vol. 6, June, 1923, pp. 730–741; Refractory possibilities of some Georgia clays: Jour. Am. Cer. Soc., vol. 6, May, 1923, pp. 663–673. Bole, G. A., and Stull, R. T., Use of sedimentary kaolins of Georgia in white ware: Jour. Am. Cer. Soc., vol. 6, July, 1923, p. 854.

[2] Middleton, Jefferson, Clay in 1923: Mineral Resources of the United States, 1923, pt. II, p. 77.

The total production of white clay or kaolin for 1923 is given as 336,803 tons and, in addition to the above uses, covers an item as "unspecified" amounting to 48,705 tons, in which is included, with special ceramic uses, the following additional uses: Clay used for ink, matches, peanut coating, phonograph records, soap, stove polish, and wall paper—all filler uses in addition to the above.

The chemical analyses and most of the determinations of physical properties were made at the Southern experiment station of the Bureau of Mines at Tuscaloosa, Ala.

ACKNOWLEDGMENTS

Acknowledgments are due to the many owners of clay properties who supplied samples, and to the manufacturers who performed the compounding tests. The Central of Georgia R. R., near whose lines many of the deposits occur, assisted materially in the collection of samples, and otherwise cooperated in the work. R. E. L. Carson and L. R. Rayfield, who held fellowships maintained by the University of Alabama, in connection with the cooperative work between the State of Alabama and the Bureau of Mines, acted as laboratory assistants and gave valuable service.

LOCATION OF DEPOSITS

Samples from all known deposits could not be collected and tested, so representative samples were taken from the different districts to show the extent of the available area. Only those Georgia clay deposits were sampled which promised to be or were of economic importance as to size, thickness of cover, and transportation facilities. Alabama clays are practically undeveloped, and in order to determine the characteristics of clays from different localities samples were received from some deposits of unproved economic value.

The general area in which the deposits occur extends as a belt across middle Georgia, into Alabama, and up to the northern end of the boundary between Alabama and Mississippi. This area is part of the coastal plain region. The Georgia clays were evidently derived from the decomposition of the crystalline rocks of the Piedmont Plateau to the north, and some of the Alabama clays are from similar rocks to the northeast. The deposits near Fort Payne, Ala.,[3] are the only ones sampled that occur outside of the coastal plain.

The clay beds range in thickness from those too thin to work profitably, up to more than 40 feet. The thickness of cover ranges from a few inches up to depths that make stripping impracticable.

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[3] Ries, H., Bayley, W. S., and others, High-grade clays of the eastern United States: U. S. Geol. Survey Bull. 708, 1922, p. 128.

At some places 50 to 60 feet of cover has been stripped to expose the clay.

The geology of the district and detailed descriptions of some of the deposits have been given in Federal and State reports.[4]

Table 1 gives the locations of the deposits sampled and the nearest railway shipping points.

TABLE 1.—*Sources of clay tested*

Sample No.	Location of deposit	Sample No.	Location of deposit
G-1	Gordon, Ga.	G-34	Toomsboro, Ga.
G-2	Do.	G-35	McIntyre, Ga.
G-4	Do.	G-36	Do.
G-6	McIntyre, Ga.	G-37	Toomsboro, Ga.
G-7	Claymount, Ga.	G-38	Wrileys, Ga.
G-8	Griswold, Ga.	G-39	Toomsboro, Ga.
G-9	McIntyre, Ga.	G-40	Wrileys, Ga.
G-15	Gordon, Ga.	G-41	Toomsboro, Ga.
G-16	Butler, Ga.	G-42	Do.
G-17	Do.	G-43	Wrileys, Ga.
G-22	Perry, Ga.	G-44	Gordon, Ga.
G-24	Nakomis, Ga.	A-1	York, Ala.
G-26	McIntyre, Ga.	A-2	Fort Payne, Ala.
G-27	Hephzibah, Ga.	A-3	Do.
G-28	Do.	A-4	Do.
G-29	Dry Branch, Ga.	A-5	Do.
G-30	Do.	A-6	Brilliant, Ala.
G-31	Do.	A-7	Margerum, Ala.
G-32	Do.	A-8	Hackleburg, Ala.
G-33	Cuthbert, Ga.	A-9	Clayton (Baker Hill), Ala.

COLLECTION OF SAMPLES

Two classes of samples were collected. When large-scale or semicommercial tests were not to be made, the samples were reduced to about five pounds and sent directly to the Southern experiment station. When large-scale washing tests and plant compounding-tests were to be made large-size samples of 500 to 2,000 pounds were taken and shipped to the Bureau of Mines ceramic station at Columbus, Ohio, for washing. Small lots of the larger samples were sent to the Southern experiment station for laboratory washing, chemical analysis, and physical tests. The samples collected were always crude or unwashed clay. Care was taken to obtain average samples that were representative of the deposit as it was or could be mined.

PREPARING AND WASHING SAMPLES

All the clays contained impurities, consisting mainly of grit, or quartz grains, mica, and feldspar. For commercial use practically all clays should be washed or refined, hence all samples were given the same treatment which yielded a finished product such as could be produced on a commercial scale. At the same time, it was possible to determine approximately the yield or percentage of refined clay obtainable, a matter of much importance in determining the value of a clay property.

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[4] Ries, H., Bayley, W. S., and others, High-grade clays of the eastern United States: U. S. Geol. Survey Bull. 708, 1922, 314 pp.; Ries, H., Preliminary report on the clays of Alabama: Alabama Geol. Survey Bull. 6, 1900, 220 pp.; Smith, E. A., and McCalley, Henry, The mineral resources of Alabama: Alabama Geol. Survey, 1904, 79 pp.; Veatch, Otto, and Stephenson, L. W., Geology of the coastal plain of Georgia: Geol. Survey of Georgia Bull. 26, 1911, 466 pp.; Ladd, G. E., Clays of Georgia: Geol. Survey of Georgia Bull. 6-A, 1898, 199 pp.

DRYING AND GRINDING

The samples were first dried and then crushed and ground to about 35 mesh. Care was taken to prevent excessive grinding which would crush or pulverize the quartz grains, making their subsequent removal more difficult. A small jaw crusher and disk grinder were used to reduce the small samples. The large samples sent to the ceramic experiment station were similarly treated.

WASHING

Stull and Bole [5] have described the method of washing the large samples. The dried press cake was shipped to the Southern experiment station to be pulverized in a Raymond No. 0000 pulverizer. When these samples were washed, the operation was adjusted to make a finished product equal in particle size to that made in the laboratory washer at the Southern experiment station.

The small samples were prepared in the laboratory washer shown in Plate I, *A* (p. 12). The blunger consists of a 6-gallon Dasey churn driven by a one-eighth horsepower motor. Three kilos of clay sample were charged directly to this with enough water to make a 15 per cent slip. The proper amount of NaOH was added to obtain maximum dispersion or deflocculation. This quantity was determined for some of the samples by the viscosity method and for others by the settlement method. These methods have been described by Bleininger and Fulton,[6] Sproat,[7] and Schurecht,[8] to whose works the reader is referred. The percentages of alkali used, based on dry clay weights, are given in Table 2 (p. 8).

When the blunging was completed, the overflow from the blunger was opened and a constant water feed turned into the churn with the blunger still running. The overflow passed to and down the central tube of the separating tank nearly to the bottom of the cone. The coarser particles settled out and the finer rose with the upward current in the tank and flowed over the edge into the circular trough into the large settling tank or can. The rate of flow of feed water was so regulated from a constant-head tank that the rising current of water in the separating tank or sorting column had a velocity of 0.20 mm. per second. The fresh water from the constant-head tank first discharged into a "splitter" by which part of the flow was diverted directly to the separator during the early part of the operation. In this way the density of the slip in the separator was lowered at the start until the slip in the blunger became more dilute. The washing was continued until the blunger contained practically clear water. The operation was then stopped, the contents of the separator allowed to settle a short time, and the upper two-thirds of it siphoned over into the overflow. The contents of the overflow collecting tanks were then neutralized with acetic acid, the clay allowed to settle, and the excess water siphoned off. The settled material in the separator contained a large amount of fines which were drawn off through a plug in the bottom and returned to the blunger, the process was then repeated, giving the effect of a double washing. The overflow was added to the first washing.

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[5] Stull, R. T., and Bole, G. A., Washing tests of Georgia clays: Jour. Am. Cer. Soc., June, 1923 p. 730.

[6] Bleininger, A. V., and Fulton, C. E., The effect of acids and alkalies upon clays in the plastic state: Trans. Am. Cer. Soc., vol. 14, 1912, p. 827.

[7] Sproat, I. E., Refining and utilization of Georgia kaolins: Bull. 128, Bureau of Mines, 1916, 59 pp.

[8] Schurecht, H. G., Use of electrolytes in the purification and preparation of clays: Tech. Paper 281, Bureau of Mines, 1922, 47 pp.; Elutriation tests on American kaolins: Jour. Am. Cer. Soc., May, 1920, p. 359.

The separating tank was 10 inches in diameter with a straight side height of 20 inches. The conical bottom had a slope of 60° and terminated in an outlet 1 inch in diameter, which was closed by a rubber tube and pinchcock. The tank was of copper, tinned inside, with the top edge carefully leveled to get an overflow around the entire circumference.

The thickened slip was removed to a pressure tank or "montejus" made from an ordinary 30-gallon hot water tank. The outlet in the bottom of the tank was connected to a three-leaf laboratory filter press. By allowing the inlet compressed-air pipe to extend nearly to the bottom of the "montejus," it was possible to keep the contents agitated by allowing a small amount of air to flow and escape through a relief valve slightly opened. Air at 90 pounds pressure was available, but a pressure of 75 to 80 pounds was used in filtering. The inlet-air pipe should be fitted with a check valve to prevent a drop in air pressure siphoning the clay slip back into the line.

Some clays showed a tendency to run through the filter cloth. To overcome this tendency, a sheet of filter paper was placed over the cloth. The press cake was dried, broken up, and ground 30 minutes in a porcelain-jar pebble mill. No attempt was made to reduce the individual clay grains, but simply to pulverize the cake. The coarse material was dried and weighed to determine its percentage of the original sample.

RESULTS OF WASHING

Some loss of clay in washing and handling was unavoidable, but the sum of weights of washed clay and residue usually checked fairly well with the original.

The washing properties of the clays tested are given below. Table 2 shows the clay yields based on the difference between the weight of the original sample and the residue.

G–1. Difficult to slake and get into suspension. A large amount remained unslaked in the form of rounded granules. Finer grinding or slaking before drying would probably produce better results. Settled slowly when acid was added and filtered with difficulty.

G–2. Slaked and went into suspension with some difficulty, but more easily than G–1. Settled rapidly and filtered easily.

G–4. Easy working clay, slaked and filtered readily.

G–6. Slow slaking, but settled and filtered well.

G–7. Slaking properties fair; settled easily and filtered clear, but rather slowly.

G–8. Slaked fair and could be held in suspension as long as agitated. No NaOH used. Settled rapidly, filtered easily.

G–9. Easily washed and filtered.

G–15. ———.

G–16. No NaOH used. Easily slaked. Settled and filtered easily.

G–17. No NaOH used. Easily slaked, but difficult to disperse and hold in suspension as it tended to settle rapidly. Filtered easily.

G–22. Slaked, settled, and filtered easily.

G–26. ———.

G–27. Slaked and dispersed readily. Settled rather slowly. Inclined to run through filter.

G–28. Slaked and dispersed readily. Settled well. Filtered about the same as G–27.

G–29. Slaked and dispersed readily without aid of NaOH. Filtered slowly.

G–30. Slaked, dispersed and filtered well.

G–31. Slaked, dispersed, settled and filtered well.

G–32. Slaked and dispersed well. Filtered slowly.

G–33. Slaked and dispersed well. Filtered rapidly.

G–34. Difficult to slake, lumps left in residue, should probably be ground finer or slaked without drying. Filtered with difficulty.

G–35. Slaked and dispersed well. Filtered easily.

G–36. Slaked and dispersed well. Filtered slowly.

G–37. Slaked, dispersed, and filtered well.

G–38. Slaked and dispersed fairly well, but difficult to filter.

G–39. Slaked, settled, and filtered easily.

G–40. Do.

G–41. Worked fairly well.

G–42. Slaked fairly well. Difficult and slow to filter.

G–43. Slaked slowly. Difficult to filter.

G–44. Slaked and filtered fairly well.

A–1. Slaked fairly well. Settled and filtered easily.

A–2. This clay was halloysite and was not washed.

A–3. Dispersed, settled, and filtered readily.

A–4. Worked fairly well.

A–5. Settled and filtered exceptionally well.
A–6. Slaked, dispersed, and filtered easily.
A–7. Do.
A–8. Washing properties only fairly good.
A–9. Slaked, settled, and filtered easily.

CHEMICAL ANALYSES AND GENERAL PHYSICAL PROPERTIES

CHEMICAL ANALYSES

Table 2 gives chemical analyses of the washed clay and of the residue obtained from the washing operation. The residue rather than the crude clay was analyzed to emphasize the effect of washing on purification. In addition to the oxides shown, there were also present varying amounts, from small quantities to traces, of lime, magnesia, phosphorus, and sulphur. These were not determined, as their presence in such small quantities would not affect the filler properties of the clays. Analyses of the residues from the Alabama clays were not made.

It will be noted that most of the Georgia clays are nearly normal, with an analysis approximately that of kaolinite. The only exceptions are G–2 and G–33, which are bauxitic, and G–43, which is siliceous. Of the Alabama clays, A–5, A–8, and A–9 are approximately normal, and the rest are siliceous. Clay A–2 is a halloysite and does not slake in water. It was prepared by grinding in a pebble mill. With the exception of A–1 and A–3, the Alabama clays are very low in alkalies.

For filler use, the physical properties are more important than the chemical composition of a clay, as long as the clay is approximately a kaolin.

The general physical properties, determined because they have more or less bearing on the value of a clay for all filler purposes, were true specific gravity, apparent specific gravity or weight per unit volume of the pulverized clay, grit, or residue retained on a sieve with an arbitrarily selected size of opening, color in the dry state, oil absorption when mixed with oil, and particle size or fineness of grain.

TABLE 2.—*Chemical analyses and washing properties*

Sample No.	Per cent NaOH for maximum dispersion	Per cent of total clay recovered as washed clay	Effect of washing on color	Chemical analyses										
				Washed-clay analyses, per cent						Analyses of residue from washing, per cent				
				SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Na_2O, K_2O	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Loss on ignition
G-1	0.12	49	Improved	45.18	39.08	0.71	0.47	0.51	13.70	49.31	35.25	1.22	1.24	12.55
G-2	.24	70	do	32.11	46.82	.93	.57	.53	18.67	30.00	47.48	1.05	1.14	20.13
G-4	.16	74	do	44.35	40.77	.78	.47	.34	14.00	45.57	38.86	.74	1.08	13.70
G-6	.45	65	do	44.27	40.45	.70	.44	.66	13.64	50.56	35.21	.91	1.22	12.14
G-7	.36	79	do	44.68	40.09	1.00	.53	.33	13.78	44.27	37.83	1.56	1.74	13.06
G-8	.00	83	do	44.90	39.81	.65	.47	.36	13.46	71.77	19.73	.97	1.30	5.67
G-9	.20	74	do	44.26	40.05	.85	.47	.39	13.61	86.47	9.19	.74	.80	2.76
G-15	.40	90	do	43.89	40.70	.70	.41	.46	13.81	44.58	39.33	2.23	1.71	11.80
G-16	.00	71	do	45.07	39.30	1.07	.38	.42	13.48	50.10	36.01	.91	1.21	11.88
G-17	.00	68	do	45.08	40.08	.50	.59	.49	13.16	56.77	29.96	1.31	1.27	9.87
G-22	.30	90	do	43.24	41.25	.72	.50	.39	14.08	45.17	38.76	1.14	1.28	13.46
G-24	------	------		43.75	39.16	1.09	1.30	.25	14.47	------	------	------	------	------
G-26	.20	93	Improved	44.27	41.08	.72	.50	.39	13.60	46.89	37.56	.74	1.72	13.02
G-27	.30	81	Slightly improved	44.28	40.51	.78	.47	.45	13.69	44.81	39.94	.76	.81	14.03
G-28	.30	80	No change	44.28	40.66	.64	.44	.52	13.68	44.90	39.85	.80	1.21	13.71
G-29	.00	79	Improved	44.37	39.96	.43	.57	.35	13.81	45.19	39.17	.80	1.19	13.74
G-30	.30	86	do	43.96	39.98	.65	.57	.48	13.84	45.09	38.98	.69	.97	13.74
G-31	.50	95	do	44.50	39.51	.85	1.07	.34	13.71	44.59	39.48	1.14	1.20	13.30
G-32	.10	90	do	44.66	39.80	.50	.64	.39	13.54	48.21	36.49	1.23	1.19	12.52
G-33	.10	73	Slightly improved	38.78	43.46	.48	.74	.49	15.78	38.38	44.43	1.25	1.14	15.95
G-34	.10	57	Improved	44.01	39.71	1.14	.74	.37	13.79	44.49	38.97	1.28	1.15	13.56
G-35	.50	75	Slightly improved	44.26	40.11	.71	.90	.43	13.85	44.83	39.03	1.17	1.41	13.54
G-36	.30	89	do	43.70	40.27	.74	1.04	.43	13.53	44.11	40.72	.91	1.61	12.57
G-37	.30	86	Improved	44.11	40.45	.71	1.05	.37	13.58	44.27	39.55	.63	1.61	13.42
G-38	.50	61	do	44.85	39.74	.92	.93	.39	13.64	45.47	38.29	.80	1.36	13.12
G-39	.50	97	do	44.50	39.56	.78	.60	.41	13.70	47.58	36.73	.91	1.57	12.59
G-40	.50	78	do	44.36	39.81	1.56	.81	.51	13.41	44.07	39.19	1.17	1.33	13.28
G-41	.10	42	do	44.21	39.21	1.56	.93	.49	13.40	45.14	37.94	1.45	1.26	13.86
G-42	.10	35	do	44.30	40.01	1.42	1.09	.32	13.32	44.32	38.70	1.14	1.00	13.43
G-43	.20	36	No change	46.50	36.17	1.97	1.05	.57	12.72	51.31	33.66	1.24	1.32	11.36
G-44	.20	62	Slightly improved	44.62	40.13	.85	1.12	.41	13.39	48.82	36.01	.92	1.04	12.32
A-1	.50	62		50.92	34.91	.94	1.14	1.06	10.73	------	------	------	------	------
A-2	Not.	Washed.		48.60	36.77	.74	Trace.	.19	14.02	------	------	------	------	------
A-3	.50	76		55.12	30.98	1.37	1.61	.68	9.75	------	------	------	------	------
A-4	.40	79		53.57	32.80	.94	1.69	.19	10.84	------	------	------	------	------
A-5	.30	70		44.34	39.57	.77	1.68	.17	13.66	------	------	------	------	------
A-6	.30	22		48.94	35.49	1.17	1.48	.37	12.46	------	------	------	------	------
A-7	.30	62		51.68	33.81	1.31	1.39	.27	11.96	------	------	------	------	------
A-8	.50	75		45.07	38.96	.97	1.53	.31	13.58	------	------	------	------	------
A-9	.50	69		44.23	39.15	1.31	1.56	.27	13.75	------	------	------	------	------

TRUE SPECIFIC GRAVITY

Specific gravity determinations were made of samples dried at 105° C. They were performed in the ordinary way with a pycnometer bottle. All pycnometer bottles used were carefully calibrated. Table 3 gives the results.

APPARENT SPECIFIC GRAVITY

The apparent specific gravity or weight per unit volume of the dry, pulverized clay is a property whose value, as determining the best use of a clay, is doubtful. It is a measure of the fluffiness or packing qualities of the powdered clay under its own weight. It apparently has no relation to the other physical properties, with the exception of oil absorption. Table 3 indicates that to some extent the oil absorption varies inversely as the weight per unit volume.

This quality was determined by a Scott volumeter, which consists of a series of small glass baffles, one above the other, set at such an angle that the powdered clay will slide freely from the lower edge of one to the top of the other. The clay, dried at 105° C. and then cooled under atmospheric conditions, is fed into the top baffle through a 20-mesh screen to break up any lumps. The bottom baffle discharges into a short funnel, under which is a cubical measure holding exactly 1 cubic inch. The measure is allowed to fill completely and run over. It is then struck off with the edge of a stiff spatula and weighed. Results are given in Table 3.

GRIT OR COARSE GRAINS

The amount of coarse grains or particles in a clay is of importance for practically all filler purposes, but more especially so for paper, rubber, and paint. If the coarse particles are quartz, they are particularly objectionable in paper. In paint they increase the cost and time of grinding, and in rubber may cause points of weakness where rupture may start.

No standard of fineness has been adopted, even in any one industry. Since 300 to 350 mesh screens are the finest that so far can be made with any degree of accuracy, they are commonly used as a standard.

The samples tested were screened on a 325-mesh sieve with nominal openings of 0.044 mm. and maximum openings not over 0.070 mm. on the longest side. Twenty grams of the dried clay were taken for the screen test, and washed on the sieve with a gentle spray of water. The screen with the residue was dried on a hot plate and the residue weighed.

Table 3 shows grit or residue and its mineralogical character.

OIL ABSORPTION

The amount of oil that a clay will absorb before it is saturated is important for all uses that require linseed or other oils in compounding or as a vehicle. Chief of these uses are for paint, oilcloth, linoleum, and phonograph records. The reason is evident, as the cost of linseed oil per pound is many times that of clay, and the oil absorbed by the clay is lost as far as volume and covering properties are concerned. Different methods of determining this value are in use by the different manufacturers. Some use comparative methods, in which oil is worked with the clay up to the consistence used in the finished product, and the amount of oil required is compared with that of a standard material.

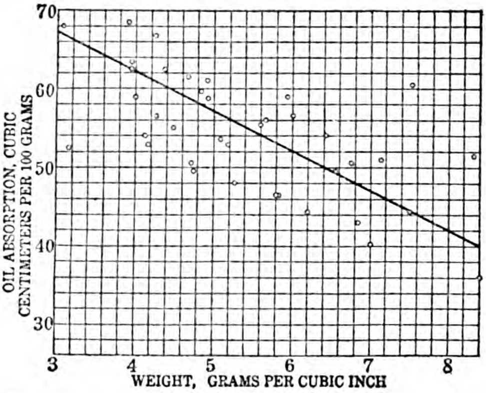

FIGURE 1.—Relation between oil absorption and unit weight

To obtain the results given in Table 3, the oil absorption was determined by the method developed by Gardner and Coleman.[9] The pulverized clay was dried at 105° C. and cooled under room conditions. Twenty grams of the clay was weighed out and placed in a thick, round-bottomed glass. Linseed oil was slowly added from a burette and the clay lightly stirred with a stiff spatula until all the clay was wet. It generally formed a single lump or ball. The end point was just before the oil began to show on the surface of the lump, at which time it began to smear the sides of the glass. The results are reported as cubic centimeters of oil per 100 grams of clay.

It was thought that some definite relationship would be found between the oil absorption and the average particle size, but the results were so conflicting that no conclusions could be drawn. There is, however, some relation between oil absorption and bulk or weight per unit volume of the powdered clay. Figure 1 shows the results of plotting the oil absorption values and unit weights given in Table 3. Although results vary widely, there is evidence of a general tendency and a curve has been drawn as representing an approximate average.

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[9] Gardner, Henry A., and Coleman, R. E., Oil absorption of pigments: Paint Manufacturers Association of the United States, Circular 85, Educational Bureau, Scientific Section, 1920, 13 pp.

TABLE 3.—*Physical properties of clays tested*

Sample	Specific gravity	Grams per cubic inch	Oil absorption, c. c. oil per 100 grams clay	Retained on 325 mesh, per cent	Minerals in residue on 325 mesh in order of amounts
G-1	2.547	7.018	40.2	0.14	Kaolinite, feldspar.
G-2	2.547	5.826	46.5	.30	Kaolinite, quartz.
G-4	2.591	5.988	56.5	.30	Do.
G-6	2.591	8.159	51.7	.08	Kaolinite, quartz, mica.
G-7	2.602	5.655	56.0	.02	Do.
G-8	2.577	5.946	59.0	.04	Kaolinite, mica, quartz.
G-9	2.589	4.924	58.5	.04	Kaolinite, quartz, mica.
G-15	2.601	3.942	62.5	.04	Kaolinite, mica, quartz.
G-16	2.585	7.496	44.5	.43	Mica, kaolinite, quartz.
G-17	2.615	4.164	53.0	2.00	Do.
G-22	2.540	7.510	44.5	1.07	Kaolinite, quartz, mica.
G-24	2.565	3.086	68.0	.02	Quartz, kaolinite, mica.
G-26	2.575	3.992	59.0	1.20	Kaolinite, mica, quartz.
G-27	2.598	4.732	50.5	.40	Do.
G-28	2.595	4.726	49.5	.20	Do.
G-29	2.570	5.799	46.5	.10	Kaolinite, mica.
G-30	2.501	4.121	54.0	.13	Kaolinite, mica, quartz.
G-31	2.596	4.832	59.5	.07	Do.
G-32	2.537	5.078	53.5	.03	Kaolinite, mica, quartz, feldspar.
G-33	2.575	4.463	55.0	.06	Do.
G-34	2.564	4.656	61.5	.08	Kaolinite, quartz.
G-35	2.590	4.267	56.5	.03	Do.
G-36	2.623	3.930	63.5	.04	Kaolinite, quartz, feldspar.
G-37	2.611	5.261	48.0	.50	Do.
G-38	2.595	5.605	55.5	.17	Do.
G-39	2.605	6.196	44.5	.36	Kaolinite, quartz, mica.
G-40	2.623	3.896	68.5	.04	Do.
G-41	2.614	4.373	61.5	.03	Do.
G-42	2.625	4.247	67.0	.07	Kaolinite, quartz, mica, feldspar.
G-43	2.636	6.549	49.5	.30	Kaolinite, quartz, feldspar.
G-44	2.622	4.673	53.5	.13	Kaolinite, mica, quartz, feldspar.
Paper clay A	[b] 2.600	---------	---------	.17	Quartz, mica, kaolinite.
Paper clay B				.29	Mica, quartz, kaolinite.
Paper clay C				.80	Mica, kaolinite, quartz.
Paper clay D				.27	Feldspar, kaolinite, quartz, mica.
A-1	2.604	7.521	60.5	.06	Quartz, kaolinite, mica.
A-2	2.563	8.414	36.0	[a] 9.51	Halloysite.
A-3	2.595	7.142	51.0	.09	Kaolinite, quartz, iron oxide.
A-4	2.599	4.928	62.5	.10	Kaolinite, iron oxide, quartz.
A-5	2.570	3.144	52.5	.38	Kaolinite, quartz.
A-6	2.617	6.741	50.5	.12	Kaolinite, quartz, feldspar.
A-7	2.631	6.421	54.0	.21	Do.
A-8	2.630	6.850	43.0	.20	Do.
A-9	2.593	5.187	53.0	.15	Kaolinite, quartz, mica.

[a] Clay A-2 was not washed, only ground in pebble mill.
[b] Assumed, not determined.

AVERAGE PARTICLE SIZE

The fineness of grains of a clay is of importance in nearly every use as filler, especially so for rubber and paint. Not only is the average size important, but the relative distribution of the different sizes, from coarsest to finest, is almost of equal value in judging the use for which a clay is best suited.

A method of determining the average particle size and distribution of sizes has been described by the author[10] who has used it in determining the particle size of the samples of Georgia and Alabama clays. For filler use, the diameter of the particles, calculated on the basis of the specific surface or total surface per unit weight, gives results that are more comparable than does the average diameter calculated on the basis of volume. For this reason the figures in Table 4 were calculated on the basis of specific surface. The various sized particles are also grouped and their percentages as given in the table were calculated on the basis of the ratio of the surface exposed by each size to the total surface. In the table, diameters of particles are given in microns (1 micon=0.001 mm. or 0.000039 inch).

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[10] Weigel, W. M., The size and character of grains of nonmetallic mineral fillers: Tech. Paper 296, Bureau of Mines, 1924, 44 pp.

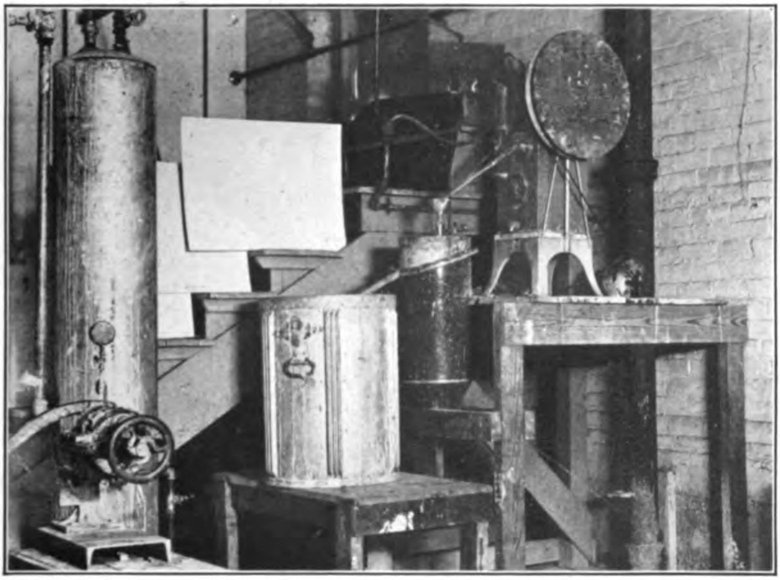
Samples B and C in the table were English paper clay and were included for comparative purposes to show the general difference in average-particle size between the residual kaolins and sedimentary or transported clays.

Table 4.—*Average diameters and percentages of different-sized grains in Georgia and Alabama clays*

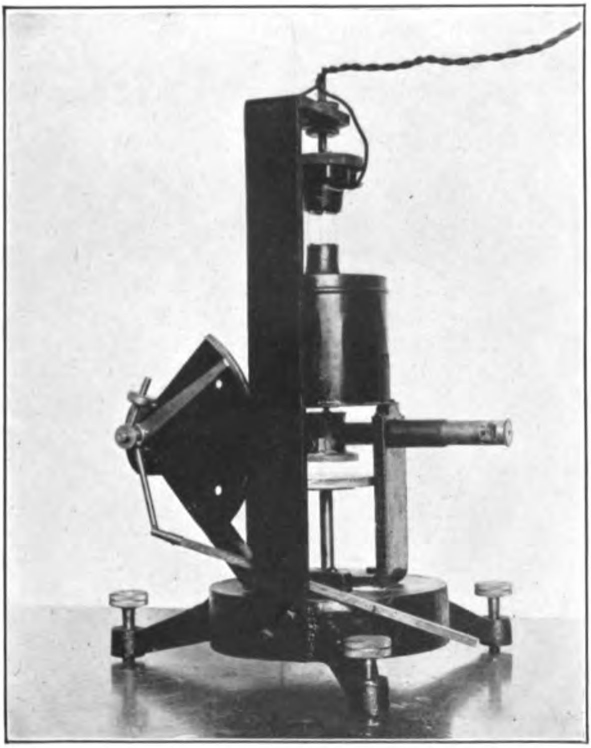
Sample	Average diameter	Diameters and percentages										
		60	50	40	30	20	15	10	7	5	3	1
G-1	4.4	0.14	0.41	0.26	0.90	1.99	2.84	6.35	7.33	12.13.	23.19	44.43
G-2	3.3			.14	.89	.99	2.15	4.50	6.37	7.40	19.84	57.71
G-4	2.9	.14		.19	.77	1.27	1.21	1.87	3.26	5.86	25.35	60.09
G-6	2.4	.10	.19	.33	.66	.33	.51	1.48	1.75	5.13	16.45	73.08
G-7	3.3		.08	.28	.56	1.58	2.16	3.64	5.59	8.68	19.19	58.23
G-8	3.7	.12	.36	.35	.96	1.27	2.21	3.38	6.23	8.67	22.11	54.34
G-9	3.2		.18	.35	1.11	.82	1.25	3.20	4.23	7.93	23.93	56.97
G-15	4.1	.09	.25	.48	.90	1.93	2.89	5.36	7.76	10.68	15.66	54.01
G-16	6.0	.35	.42	.95	2.24	2.92	4.99	7.79	9.49	13.67	22.53	34.63
G-17	5.6	.64	.22	.92	2.16	3.29	4.11	5.19	9.01	12.08	23.65	38.72
G-22	5.2	.13	.38	1.04	3.19	4.20	3.96	4.16	4.72	6.30	16.72	55.19
G-24	2.9		.08	.16	.47	.53	1.18	2.13	6.40	9.74	21.70	57.61
G-26	5.0	.40	.56	.60	1.81	2.27	2.90	5.48	8.81	12.36	19.65	45.16
G-27	3.9	.42	.29	.38	.72	1.51	1.80	3.97	4.67	5.10	29.25	51.86
G-28	4.0		.10	.24	1.08	1.56	3.00	5.41	6.88	11.89	22.48	47.35
G-29	3.3		.23	.22	1.09	1.51	2.21	3.44	3.41	5.95	19.80	62.12
G-30	3.3	.18	.26	.17	.99	1.01	1.62	3.31	4.37	7.57	20.22	60.29
G-31	3.4	.46	.54	.34	1.82	1.54	1.02	1.96	2.67	3.85	12.36	73.42
G-32	3.2	.33	.34	.22	.77	1.18	1.17	2.67	5.17	5.83	18.30	64.01
G-33	3.3	.35	.24	.65	1.36	.97	1.09	2.42	3.96	5.75	14.19	69.01
G-34	2.8			.07	1.00	1.18	1.00	2.29	5.32	8.23	12.75	68.16
G-35	3.3		.14	.38	1.26	.97	1.52	2.27	4.97	8.09	23.49	56.89
G-36	3.4	.13	.20	.25	.77	1.64	2.34	3.87	5.53	7.66	14.63	62.98
G-37	3.5	.17	.25	.16	.62	1.14	2.48	3.68	5.32	8.38	22.07	55.71
G-38	2.7	.34	.23	.90	1.45	.75	.50	.97	2.01	2.83	8.82	81.29
G-39	3.0	.17	.12	.47	1.16	.94	1.23	2.23	4.22	4.85	15.63	68.99
G-40	3.2	.30	.20	.26	.39	1.05	1.63	2.93	5.65	8.15	16.21	63.23
G-41	2.5			.18	.51	.73	1.74	2.97	4.12	4.79	11.71	73.25
G-42	3.2	.23	.16	.65	.61	1.73	1.46	2.48	4.88	6.76	12.51	68.52
G-43	4.5	.63	.29	.19	.85	2.46	3.82	4.63	7.64	9.33	19.80	50.37
G-44	3.9		.15	.30	.90	2.00	3.15	4.71	7.36	9.26	18.65	53.51
B	5.6	.54	.51	.53	1.38	2.49	7.40	5.99	7.01	8.49	21.57	44.09
C	6.8		1.13	1.21	2.64	3.87	7.08	9.22	10.08	13.46	16.88	34.43
A-1	4.5	.21	.41	.97	1.68	2.29	2.80	5.35	6.32	8.89	13.99	57.10
A-2	4.2	.11	.51	.61	1.29	.87	.85	2.41	4.63	4.32	8.96	73.51
A-3	2.5	.12	.07	.25	.42	.39	.68	2.88	5.14	6.21	10.59	73.24
A-4	4.0	.47	.66	.81	1.72	1.29	.92	2.21	5.21	6.64	21.42	58.64
A-5	3.7	.54	.87	.51	.89	.52	.94	1.50	4.20	6.13	31.62	52.25
A-6	2.3	.20	.07	.23	.96	.45	.82	1.21	2.15	3.18	10.43	80.30
A-7	3.0	.18	.33	1.03	1.65	.52	.63	.92	1.94	4.05	13.13	75.62
A-8	2.8	.16	.24	.38	.80	1.15	.65	1.30	2.93	6.45	18.93	67.00
A-9	3.9	.64	.59	1.12	1.75	.84	1.11	1.09	2.53	5.75	22.58	62.00

COLOR

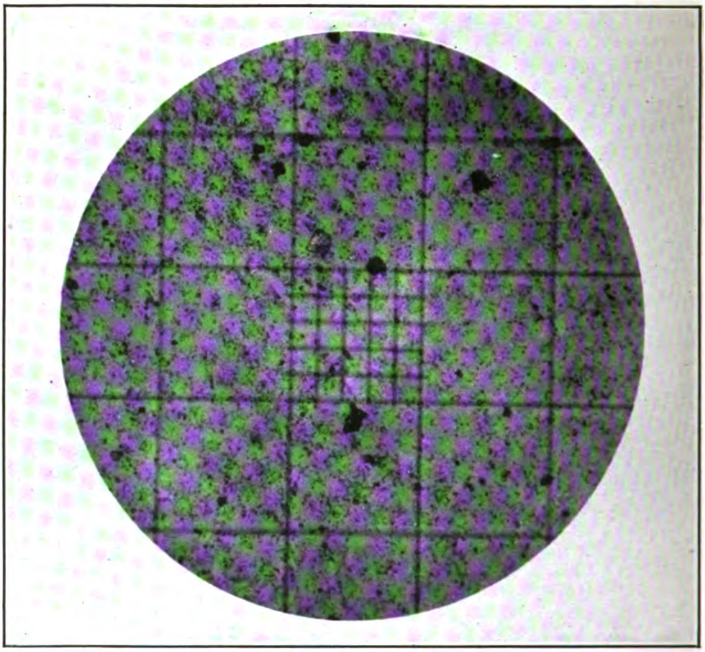
Degree of whiteness or "color" is of first importance in clay to be used in paper, paints, and oilcloth. It is of secondary importance when the clay is to be compounded with some darker material, as



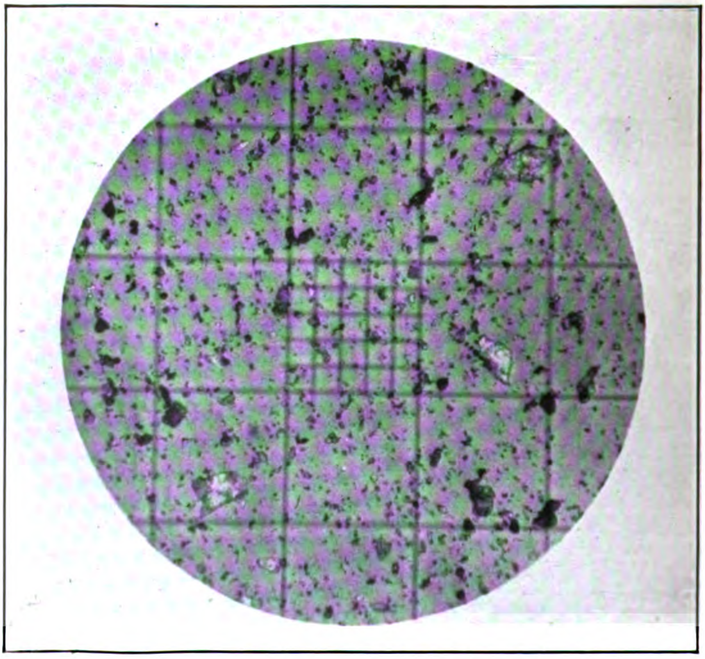
A. LABORATORY CLAY WASHER



B. PFUND CALORIMETER



A. GEORGIA KAOLIN × 100



B. ENGLISH KAOLIN × 100

rubber. For such uses, however, color is often used to indicate the purity of the product, and the whiter clays will receive more favorable consideration than those that are off color.

For use in paper the color in a dry state is all that is necessary to consider. The method of classification and determination of the relative brightness of the clays is treated under "Use in paper" on the following pages.

Many clays that are a good white when dry change to brown or dirty green when mixed with oil. Clays with this property are unsuited for use in paints. The method of test and comparison and the relative value of the clays tested for use in paints are treated under "Use in paint" on page 32.

TESTS FOR FILLER USE

USE IN PAPER

Three physical properties are of importance in determining the value of a clay as a paper filler. These are grit, color, and retention.

GRIT

For determining the amount of coarse grains or co-called "grit" three methods are in use, the centrifugal, the decantation or sedimentation, and the screen test; all three have been described in technical literature on the subject and are well known to paper technologists. The screen test, if made with a carefully selected screen, is believed to be the most practical and quickest. Table 3 gives the results of the grit test of washed clays or the percentage remaining on a 325-mesh screen.

COLOR

The color or degree of whiteness is important, especially for high-grade papers. As far as can be determined, no standard method of testing for color is in use other than the usual comparison of two or more samples placed side by side. As such a comparison can not be expressed in figures, this method will not apply to the tabulation of tests of a large number of clays. To determine the color characteristics of the clays considered, a Pfund colorimeter was used.[11] This instrument, shown in Plate I, *B*, indicates very slight variations in color and gives numerical values as a basis of comparison. Also, since the "brightness" is determined in red, green, and blue light of known wave lengths, the characteristics of the samples were determined—whether the samples were yellowish, bluish, or true gray.

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[11] For a full description of the colorimeter designed by A. H. Pfund, its principles, and method of use, see American Society for Testing Materials, A new colorimeter for white pigments and some results obtained by its use: June, 1920.

The values in Table 5 under "Color characteristics" give the reflection coefficient or degree of brightness for each color expressed as a percentage. The instrument was standardized with pure magnesium carbonate with a reflection coefficient of 0.98. Dry clay was used for all color tests.

TABLE 5.—*Color characteristics and retention tests*

Sample	Reflection coefficients or color characteristics			IV	V	VI	VII	VIII
	I	II	III	Difference between red and blue	Difference between columns II and IV	Per cent retention with 20 per cent clay	Per cent retention with 10 per cent clay	Mean or average of retentions, columns VI and VII
	Blue wave length 480 μμ	Green wave length 560 μμ	Red wave length 635 μμ					
G-1	69.8	78.7	83.0	13.2	65.5	46.4	50.5	48.4
G-2	71.7	82.8	88.2	16.5	66.3	45.3	53.1	49.2
G-4	81.2	89.0	92.1	10.9	78.1	46.8	56.0	51.4
G-6	69.0	77.9	81.3	12.3	65.6	47.3	56.8	52.0
G-7	71.7	83.0	88.2	17.1	65.9	49.0	53.9	51.4
G-8	73.7	83.7	88.2	14.5	69.2	45.1	49.3	47.2
G-9	74.5	83.5	88.3	13.8	69.7	50.7	56.1	53.4
G-15	68.9	76.8	83.0	14.1	62.7	49.1	51.7	50.6
G-16	75.0	84.0	87.7	12.7	71.3	47.4	48.7	48.0
G-17	66.8	75.0	84.0	17.2	57.8	49.4	53.8	51.6
G-22	65.3	72.1	79.7	14.4	57.7	49.5	53.2	51.3
G-24	(a)	64.5	67.2	----------	----------	52.5	58.0	55.2
G-26	77.1	85.2	90.2	13.1	72.1	49.3	53.0	51.1
G-27	75.4	85.2	89.5	14.1	71.1	44.2	50.8	47.5
G-28	69.7	81.4	88.7	19.0	62.4	43.8	50.7	49.7
G-29	77.5	84.4	89.6	12.1	72.3	45.4	47.3	46.3
G-30	80.3	88.3	92.5	12.2	76.1	45.7	54.2	49.9
G-31	76.8	85.5	90.2	13.4	72.1	46.1	55.4	50.7
G-32	78.1	87.0	90.8	12.7	74.3	45.8	51.6	48.7
G-33	74.7	82.8	87.9	13.2	69.6	48.3	51.6	49.9
G-34	80.6	87.5	91.2	10.6	76.9	52.8	54.3	53.5
G-35	81.4	87.6	92.7	11.3	76.3	46.7	54.9	50.8
G-36	77.7	84.8	90.1	12.4	72.4	45.4	51.4	48.4
G-37	78.4	86.2	91.1	12.7	73.5	47.4	54.7	51.0
G-38	81.1	80.7	86.1	15.0	65.7	49.6	56.0	52.8
G-39	71.8	82.2	89.1	17.3	64.9	48.1	53.5	50.8
G-40	77.9	84.8	89.8	12.0	72.8	45.3	54.5	49.9
G-41	81.3	87.2	90.1	8.8	78.4	46.6	53.4	50.0
G-42	71.9	81.6	87.7	15.8	65.8	44.4	54.0	49.2
G-43	66.1	71.3	78.3	12.2	59.1	40.7	48.3	44.5
G-44	70.7	82.2	87.1	16.4	65.8	44.5	47.8	46.1
A-1	64.6	67.1	71.0	6.4	60.7	44.6	45.2	44.9
A-2	67.9	77.6	83.2	15.3	62.3	48.1	48.3	48.2
A-3	65.0	69.3	76.1	11.1	58.2	45.7	43.5	44.6
A-4	66.7	74.6	81.7	15.0	59.6	45.9	46.9	46.4
A-5	69.9	82.0	88.6	18.7	63.3	48.5	50.3	49.4
A-6	67.8	75.2	81.2	13.4	61.8	47.8	50.8	49.3
A-7	68.1	74.6	80.2	12.1	62.5	41.8	47.5	44.6
A-8	67.0	71.6	80.4	13.4	58.2	45.7	51.4	48.5
A-9	67.4	77.3	79.7	12.3	65.0	45.2	53.2	49.2
Paper clay A	70.9	78.5	85.3	12.6	65.9	49.8	50.9	50.3
Paper clay B	71.8	80.0	83.9	12.1	67.9	48.2	48.6	48.4
Paper clay C	74.0	84.0	87.7	13.7	70.3	51.1	51.4	51.2
Paper clay D	79.2	84.5	87.1	7.9	76.6	47.8	52.5	50.1

[a] Too dark to determine.

By plotting the values in columns I, II, and III of Table 5 as ordinates and the wave lengths of the colors as abscissas, curves are obtained which graphically represent the color characteristics. (Figs. 2 (*A*, *B*, and *C*) and 3.) A true gray, or rather a clay that is nonselective in color, will give a horizontal line, the reflection coefficients for blue, green, and red being equal. For a true or perfect white, the values or reflection coefficients for blue, green, and red would all be 100. As the color becomes more selective—that is, shows a tint or dominant hue—the values for the reflection coefficients diverge. A clay with a decided tint may give higher reflection coefficients or be a "brighter" clay than one that looks whiter because of its lack of selectivity but is in reality darker. For example, take clays G-4 and D. D appears slightly the whiter, but if a very small amount of ultramarine is well ground up with G-4 it looks decidedly the whiter because its color has been made less selective. It is darker or less bright than it was originally

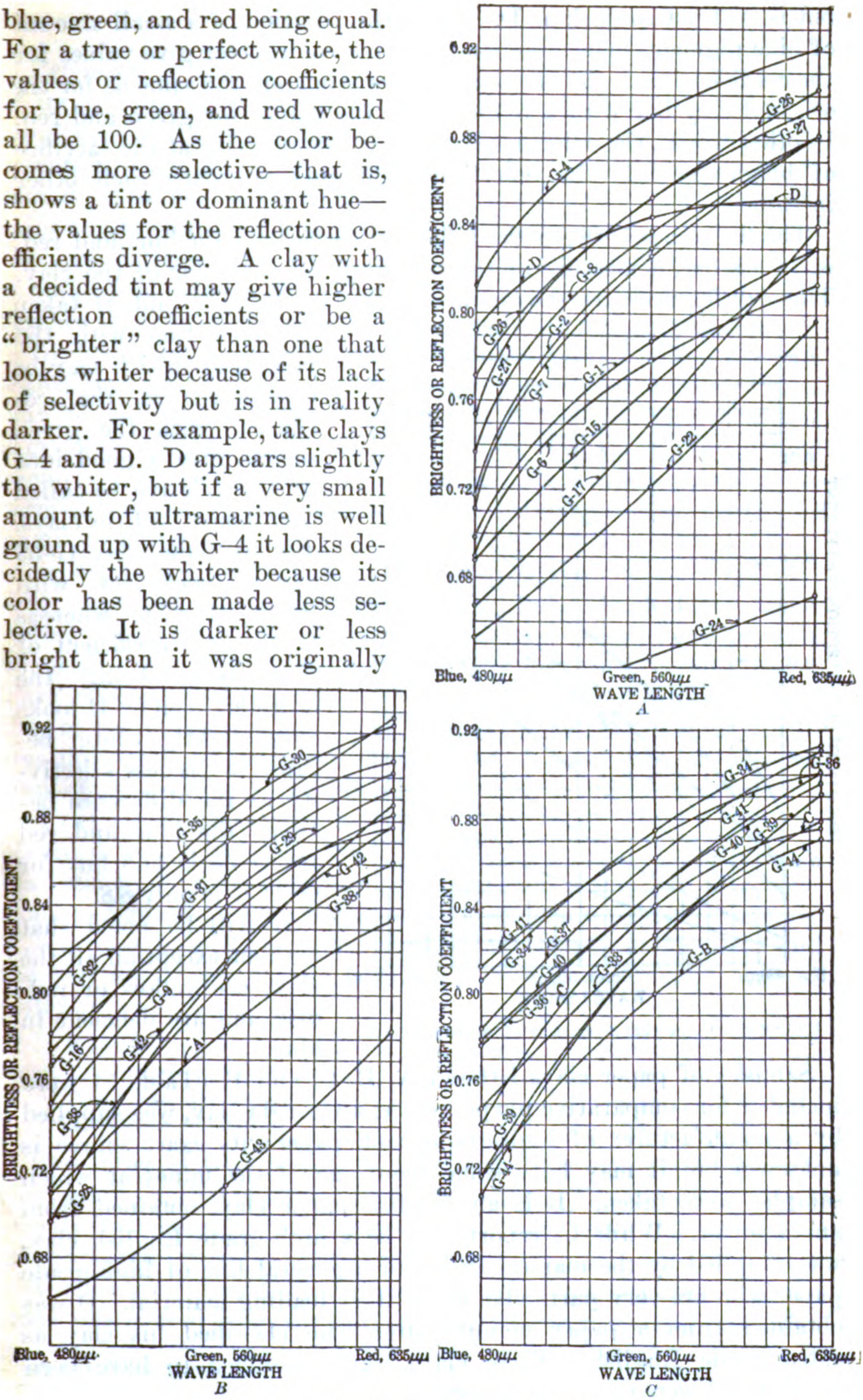

FIGURE 2.—Color characteristics of Georgia clays

but is still not so dark as D. Upon the addition of a small amount of blue pigment, determinations with the colorimeter give values for the coefficient with the blue screen approximately the same as for the original clay but with a reduction of the values for green and red. In other words, the color has been made less selective at the sacrifice of brightness and the reflection coefficients approach each other in value.

The difference between the reflection coefficients for blue and red, is, in a sense, a measure of the selectivity of the color of the clay. These differences are shown in column IV, Table 5, and, if taken in connection with the brightness which may be considered as the coefficient with the green screen, give a good idea of the relative so-called "whiteness" of the clays. For example, clay G–35 has a coefficient with green of 87.6, whereas G–41 has a coefficient of 87.2, G–35 being the brighter. But G–41 looks very slightly whiter because it has less selectivity as the difference between the blue and red for G–35 is 11.3 but for G–41 it is only 8.8.

It will be noted that without exception all the clays are yellow or reddish and are deficient in blue.

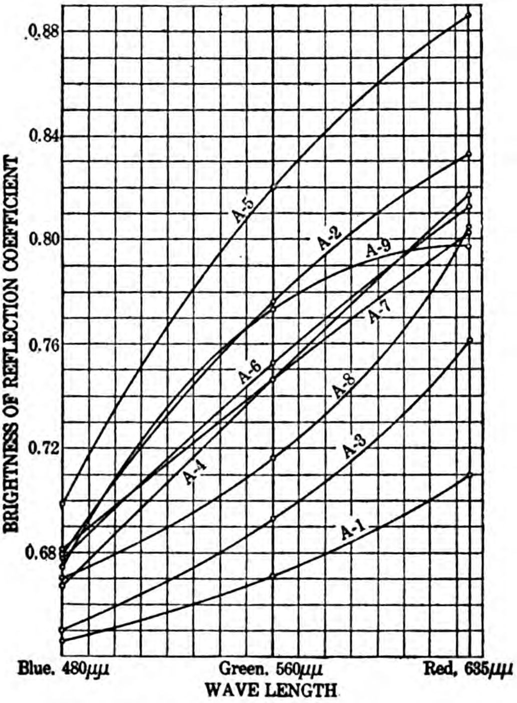

FIGURE 3.—Color characteristics of Alabama clays

Samples of paper clays lettered A, B, C, and D (Table 5) were included for comparative purposes. A, a Georgia clay, was supplied by a manufacturer of high-grade book paper; its exact source is unknown but it may have come from one of the mines at which samples were taken. B is an English paper clay, obtained from an importer. While C, reported to be a high-grade English clay, was supplied by the manufacturers of a general line of high-grade paper who are very particular about their loading material. D was obtained from a paper manufacturer who classified his clay as extra grade English. These clays were presumed to have been washed and were tested as received.

RETENTION

Retention is the most important property of a clay for paper if its grit and color are acceptable. Different methods seem to be employed in different laboratories for calculating the percentage of retention which accounts in some degree for the varying results obtained. Also laboratory tests do not generally agree with results obtained in the mill, but it is assumed that in the testing of a series of clays in the laboratory under identical conditions a fair comparison is obtainable between the different clays and that the retention difference thus obtained would be borne out fairly well in mill practice.

In determining the retention, calculations were based on the definition that retention is the proportion or percentage of the original clay furnished that is found in the finished paper. This definition is given by Sutermeister[12] and is implied by Witham.[13] The method requires the determination of the weight of finished paper, a determination that can not be made in the ordinary method of making hand sheets by dipping.

In beginning the retention tests, a laboratory beater mill was first employed. Although good checks could be obtained sometimes, just as often the results would vary by several per cent, even when all conditions of time and materials furnished were the same. This variation was taken to be due to differences in degree of beating, as the adjustable roll could not always be set the same and it was impossible to judge the exact degree of beating by an observation of the stock. A porcelain jar or pebble mill was then tried and the results were very satisfactory, as checks could always be obtained within 0.5 per cent. The jar measured 11¾ inches in diameter by 9 inches long, and was rotated at a speed of 45 revolutions per minute. The charge of flint pebbles weighed 14 pounds. The largest pebble was approximately 1½ inches in diameter and the smallest three-quarters inch. The charge or furnish was as follows:

Water	pounds	12
Dry bleached sulphite pulp	grams	50.00
Rosin size, dry weight	gram	.75
Aluminum sulphate	do	1.00

Two series of tests were run, first with 10 grams or 20 per cent clay, second with 5 grams or 10 per cent clay. The jar mill was run exactly two hours. The size and alum were made up into stock solutions and proper quantities were taken.

At the end of the run the pebbles were lifted out and rinsed off, the stock was poured from the mill, and all washings were added. The mixture was then diluted to exactly 9.1 kilos, approximately 20 pounds. To form the sheets a mold making a sheet 6 by 8 inches was used, fitted with 60-mesh Fourdrinier wire. Figure 4 shows the hand mold in detail. The frame and deckle were made of hard maple and were varnished with shellac to prevent absorption of

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[12] Sutermeister, Edwin, Chemistry of pulp and paper making. New York, 1920, p. 292.

[13] Witham, G. S., Modern pulp and paper making. New York, 1920, p. 236.

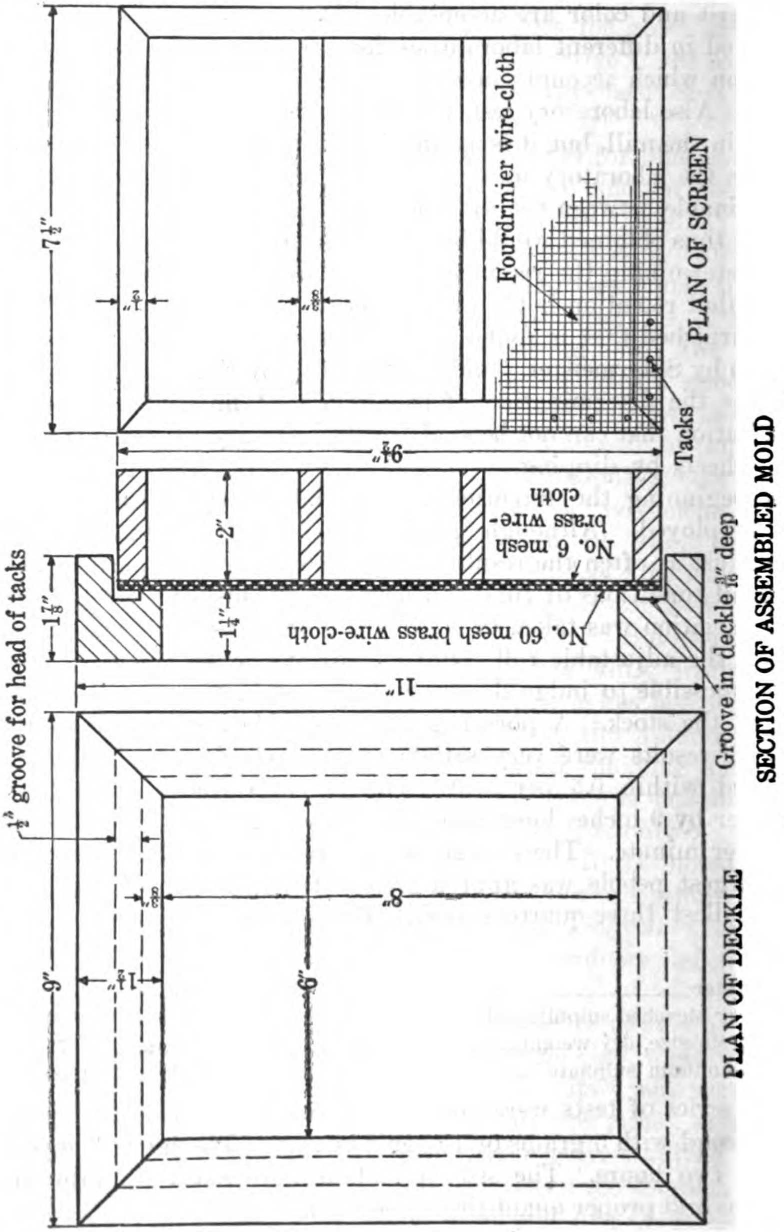
7½"
¼"
⅜"
Fourdrinier wire-cloth
PLAN OF SCREEN
Tacks
9¾"
2"
No. 6 mesh brass wire-cloth
1⅞"
1¼"
No. 60 mesh brass wire-cloth
Groove in deckle 3/16" deep
½" groove for head of tacks
11"
⅜"
8"
1¼"
6"
9"
PLAN OF DECKLE
SECTION OF ASSEMBLED MOLD

FIGURE 4.—Paper mold for making hand sheets

water. In the making of the sheets the mold was allowed to float on the surface of water in a pan. A measure holding exactly one-sixteenth of the total stock was filled and inverted over the mold and allowed to pour over the palm of the hand; then the mold was lifted from the water. A slight suction was set up under the wires until the lower edge of the frame was lifted clear. The sheets were taken up from the wire on blotting paper, pressed in a letter press, and dried between blotters on a steam drier; they were very uniform in thickness and weight. Six sheets were made from each test.

The wear of the flint pebbles introduced a complication in the calculation. This flint dust was appreciable in amount, was as fine as or finer than the clay particles, and was retained as well or better. Two methods of allowing for the dust were possible. The first was by determining the ash in a blank run without clay and deducting this from the total ash. This method was the simpler but whether the percentage retention of this material would be the same in a blank as when mixed with a much larger amount of clay was uncertain. The second was by determining the total wear from the pebbles for one run and adding this weight to the weight of clay furnished and calculating the retention on the basis of the sum of the weight of the clay and the flint dust. This second method was the one used.

To determine the wear from the pebbles, a blank charge was run, using distilled water. The total stock was carefully weighed and measured quantities were taken, evaporated to dryness and ignited. As the ash due to pulp, size, and alum from blank runs with the beater mill was known, the total material worn from the pebbles could be calculated. At the start of the tests, this weight was 1.5 grams. As the work progressed, other blanks were run which showed that the pebble wear decreased at a fairly uniform rate, as the surface of the pebbles became smoother and more polished. Toward the end of the tests, the wear of the pebbles had decreased to 1.3 and remained fairly constant, varying from 1.29 to 1.33 grams. The correction applied was then made on a sliding scale. Running the pebbles in distilled water without any pulp gave a slightly greater wear, as was to be expected because the cushioning effect and the greater viscosity of the stock were absent. The loss on ignition of the flint dust was 1.5 per cent.

The method of calculating the retention is illustrated by the following example:

CLAY No. G-26.

Loss on ignition of clay 13.60 per cent, 10 grams clay furnished.

6 sheets weighed	20.350 grams.
Weight per sheet	3.3916 grams.

Calculated weight of finished paper 3.3916×16=54.2656 grams.
10 ×0.1360=1.36 grams combined water in natural clay.
1.5×0.015 =0.0225 gram combined water in pebble grains.
1.3825 grams total combined water.
11.5 grams=10 grams clay plus 1.5 grams material ground from pebbles.
1.3825÷11.5=12.02 per cent loss on ignition of mixed clay and pebble dust.
100.00−12.02=87.98 per cent.
Ash found, 9.95 per cent.
0.9 per cent=ash due to pulp, size and alum as determined by blank run in beater mill.
9.95÷0.8798=11.31 approximate per cent filler in paper.
100−11.31=88.69 per cent stock.
0.8869×0.90=0.80 per cent correction for filled paper for ash due to pulp, size, and alum.
9.95−0.80=9.15 per cent ash due to clay and pebble dust.
9.15÷0.8798=10.40 per cent natural clay and pebble dust in finished paper.
54.2656×10.40 per cent=5.642 grams clay and pebble dust in paper.
5.642÷11.5=49.1 per cent retention.

Check run on same sample gave finished paper 54.9056 grams, ash 9.93 per cent, and 49.5 per cent retention. Average, 49.3 per cent retention.

The uniformity of the hand sheets is shown by the fact that the maximum weight of finished paper calculated for tests with 20 per cent clay was 55.60 grams for the clay showing highest retention and the minimum weight was 51.14 grams for the clay showing the lowest retention, equal to 3.475 grams and 3.196 grams per sheet of 6 by 8 inches, or 3.31 and 3.04 ounces per square yard, respectively. The variation in the case of 10 per cent clay was from a maximum of 53.58 grams to a minimum of 50.45 grams as the weight of finished paper.

SUMMARY OF RESULTS OF TESTS FOR PAPER

Table 3 gives the percentages of grit or coarse particles. With the exception of G–17, all of the samples are satisfactory in this respect. G–26 might be considered a little high, but most of the coarse particles are kaolin and so would not be as objectionable as grains of quartz and mica. Quartz grains cause excessive wear of the wires and rapidly dull the knives. Large flakes of mica appear as bright spots on the surface of the paper. A–2 is a halloysite; it will not slake in water and so can not be classed with clays. The excessive proportion of coarse particles in this sample is due to lumps of insufficiently ground material. If considered for paper, A–2 would have to be classed with talc and not with kaolin.

Color is highly important, especially for book and magazine paper. No definite standard for color has been established. Each manufacturer judges what degree of whiteness he must have, and uses a clay that meets his needs as a basis of comparison. Clays of inferior color can of course be used in inferior papers.

As pointed out under the description of the method of determining color characteristics, a nonselectively colored clay may be much darker than one that is more selective, say, with a yellowish tint, and yet compare favorably with it on visual examination. In comparing clays both these properties, selectivity and brightness, should be taken into account. This can be done by combining the results of column II and column IV, Table 5. Column II is taken as representing relative brightness and column IV as selectivity. By taking the difference between columns II and IV, the results given in column V are obtained. By taking these values in connection with the reflection coefficient for green light, it is possible to make some sort of comparison or classification with respect to color. On this basis, the following classification of the clays tested has been made:

First quality, those with a reflection coefficient, green, of not less than 80 and a difference between the reflection coefficient and selectivity, column IV, of not less than 70. This group includes samples, G–4, G–16, G–26, G–27, G–29, G–30. G–31, G–32, G–34, G–35, G–36, G–37, G–40, G–41, paper clay C and paper clay D.

Second quality, those with reflection coefficient of not less than 78 and the difference between the reflection coefficient and selectivity, column IV, not less than 65. This group would include samples G–1, G–2, G–7, G–8, G–9, G–33, G–38, G–42, G–44, paper clay A and paper clay B. The remaining 17 samples are considered as inferior or unsuitable for paper filler.

Most of the clays now used for coating are imported. However, some of the Georgia clays, notably G–4, G–30, G–34, G–35, and G–41, should be suitable if in addition to suitable color they have the required physical properties.

Retention ranks with color in fixing the value of a clay for paper filler. Columns VI, VII, and VIII, Table 5, indicating that the retentions obtained with the clays tested, compare favorably with those of other clays that are now used. For a few of the clays tested the retentions are superior. As has been pointed out, the results are comparative. Much higher results are usually obtained in mill practice than are shown here.

It is worthy of note that for all clays, with the exception of A–3, the percentage of retention with 10 per cent clay is greater than with 20 per cent. Another noticeable fact is that the range from the lowest to the highest results is not great. This seems to indicate that there is not much difference in the retentive properties of clays when refined or prepared in exactly the same way, provided the washing has been done so as to eliminate most of the coarse particles.

In the group classed as first quality in color, clays G–4, G–26, G–31, G–34, G–35, G–37, and G–41 rank first, if color and retention are considered together, while G–30 and G–40 almost equal them. In the group of second grade clays, G–7, G–9, G–33, and G–38 would rank best. In both these comparisons the arbitrary figure of 50 per cent for average retention is taken as the dividing line in the two classes.

Some of the results given above, with a discussion of the value of Georgia clay for paper fillers, have been published in a previous paper.[14]

USE IN RUBBER

The only reliable way to determine the value of a clay for rubber filler is by actual compounding and standard physical tests of the resulting compound.

METHOD OF TESTING

The cooperation of five rubber manufacturers was enlisted to carry out these compounding tests, and the results of some of the work done have been published as a separate paper.[15]

As it was impossible to receive enough cooperation to test all samples, 18 Georgia clays were selected to give an average particle size ranging from finest to coarsest, as it was assumed that the reinforcing property increases inversely with the fineness of grain and data to confirm this assumption were desired. As each manufacturer tested six samples, some of the clays could not be sent to more than one manufacturer. The manufacturers were unwilling to use a uniform compound, and preferred to use the formula they had developed for their laboratory work. As duplicate samples were tested under different conditions, it was hoped that the results could be reduced to a common basis for comparison, but the differences in compounds and in time of cure were so wide that comparison became impossible or misleading.

For purposes of comparison some of the manufacturers gave the results of tests under the same conditions of some clays now largely used in rubber. Three of these clays are marketed under trade names, and are here called X, Y, and Z; the fourth is designated as "China Clay."

As full publication of all the results at all times of cure is unnecessary, only the formula used, conditions of test, and results of the best test of each clay by each manufacturer are given. The best test is taken as the one giving the highest breaking strength. In some of the tests clays that showed a lower maximum tensile had greater stiffness at 300 and 400 per cent elongation than the one giving the higher maximum.

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[14] Weigel, W. M., Georgia clays for paper fillers: Paper Trade Rev., Aug. 9, 1923.

[15] Weigel, W. M., Georgia clays for rubber filler: The Rubber Age, July 25, 1924.

RESULTS OF MANUFACTURER A

Formula

Pale crêpe	100
Diphenylguanidine	1
Sulphur	5
Clay	52=20 volumes.

Batches were cured at 300° F for 20, 30, 40, 60, and 90 minutes. After aging 24 hours, the test pieces were broken in a Scott testing machine. Hardness was determined by a Shore durometer.

Tests by manufacturer A

Sample	Hardness	Cure	Tensile stress (pounds per square inch) and elongation								
			100	200	300	400	500	600	700	Maximum tensile	Ultimate elongation
G-6	55	30	250	500	850	1,260	1,860	2,750		3,250	650
G-4	55	60	180	430	650	980	1,450	2,160	2,980	3,200	720
G-7	56	40	250	540	830	1,250	1,920	2,760		3,150	630
G-15	55	30	180	440	750	1,150	1,800	2,660		3,020	630
G-1	55	90	250	520	780	1,100	1,580	2,200		2,800	675
G-8	55	90	240	450	660	920	1,250	1,760		2,250	675
Y	50	60	150	240	350	530	800	1,230	1,800	2,120	750

The comments of manufacturer A were as follows:

None of the samples appear to be as soft as clay Y, which is the softest clay we have used as a rubber filler. The samples G-6, G-4, and G-7 approximate closely to clay X, which is about the stiffest clay ordinarily encountered. There is a use for both grades of clay. The softer clays are for compounds where it is desired to retain a certain amount of flexibility. The stiffer clays serve to partly replace the more expensive zinc oxide and gas black where high resistance to abrasion is essential, as in tire treads.

Although these clays do not disclose any exceptional properties, we see no reason why they should not have commercial value as rubber filler, provided they are marketed with a proper regard to cleanliness, dryness, and uniformity.

RESULTS OF MANUFACTURER B

Formula

Based compound.

Smoked sheets	100
Diphenylguanidine	1
Sulphur	5
Zinc oxide (New Jersey XX)	5
	111
Clay	52

Batches were cured at 300° F. for 10, 20, 30, 40, 60, and 90 minutes, and aged 24 hours before testing. Test pieces were broken in a Scott vertical machine.

Tests by manufacturer B

Sample	Hardness	Cure	Tensile stress (pounds per square inch) and elongation							
			100	200	300	400	500	600	Maximum tensile	Ultimate elongation
G-39	61	20	270	610	1,070	1,674	2,590	....	3,510	585
Base compound	....	30	128	210	312	455	768	2,675	3,480	695
G-30	64	30	370	697	1,095	1,680	2,660	....	3,300	555
G-35	64	30	340	740	1,152	1,820	2,770	....	3,215	540
G-37	62	20	355	725	1,180	1,790	2,645	....	3,130	550
G-6	61	20	313	668	1,124	1,835	2,816	....	3,120	530
G-28	60	20	298	640	1,080	1,760	2,802	....	3,100	535
Z	....	30	313	697	1,067	1,735	2,660	....	2,900	530

The comments of manufacturer B were as follows:

> Results marked "base compound" are from the compound without any clay added. Clay Z is a commercial clay we have been using at this plant.
>
> Assuming that the clay of the most uniformly fine particle size will impart the greatest stiffness to the base stock, the data were inspected to find which of the stocks were the stiffest at 300 and 400 per cent elongation. If you will take each of the cures, and arrange the compounds in order of their stiffness at both 300 and 400 per cent, you will find that in general G–37 and G–6 are on top of the list; then comes G–28. G–35 and G–39 are about the same and follow the stiffer ones. G–30 is the lowest of the clays submitted. Our clay Z is lower in modulus than any of the Bureau of Mines clay, and of course the base stock has the lowest modulus. The 90-minute cure was so far overcured that the results are inconsistent.

The above conclusions were drawn from a study of all the results, based on tensile stress at 300 and 400 per cent elongation, hence they do not quite agree with the table, where the order is based on breaking strength only by picking out the maximum of each clay.

RESULTS OF MANUFACTURER C

Formula

First latex crêpe	49.4
Hexamethylene-tetramine	.5
Sulphur	2.9
Zinc oxide	7.2
Clay	40.0
	100.0

The batches were cured at 288° F. for 30, 45, 60, 75, 90, and 105 minutes, and were broken in a Scott machine.

Tests by manufacturer C

Sample	Hardness	Tear	Abrasion	Cure	Maximum tensile stress, pounds per square inch	Maximum elongation
G–6	65	6	965	45	3, 254	515
Clay X	69	14	747	60	3, 203	431
G–4	67	2	776	60	2, 964	488
G–30	66	Not run.	Not run.	90	2, 939	513
G–35	64	10	576	60	2, 923	456
China clay	65	2	273	60	2, 658	456
Clay Y	66	3	655	60	2, 645	423
G–26	65	4	551	45	2, 387	480
G–24	60	Not run.	Not run.	105	2, 365	550

Stresses below breaking point were not recorded. Pneumatic-tread stock, cured 50 minutes at 294°F., was taken as 1,000, the index of abrasion.

Manufacturer C's comments, considering results of all cures in addition to those given, were as follows:

> G–6 is by far the best of the lot. It tests slightly better than clay X. It has slightly better tensiles, greater elongation, same hardness, same or slightly better resistance to tear (tear for clay X was 3, 4, and 14 at 30, 45, and 60 minute cures and for G–6 was 7, 6, and 7 for the same cures), better resistance to abrasion and was slightly faster curing. G–4 and G–35 test practically the same. They appear very similar to X, but test slightly inferior to it. G–4 is slightly better than G–35. G–30 tests close to G–35, but tensiles are a little lower and cure slower and resistance to tear and abrasion slightly less. G–6, G–30, and G–35 all test better than clay Y, and much better than China clay. G–26 tests poorer than the four above. It is comparable to China clay. It shows no advantage over a large number of clays on the market. G–24 tests so poor that it is not worthy of consideration.

After the compounds had aged approximately 90 days, manufacturer C tested them again and recorded the stresses at each 100 per cent elongation to the breaking stress. Hardness, tear, and abrasion tests of the aged samples were not made. The results were as follows:

Test by manufacturer C of samples aged 90 days at room temperature

Sample	Cure	Tensile stresses (pounds per square inch) and elongation						
		100	200	300	400	500	Maximum tensile	Maximum elongation
G–6	30	421	1, 169	1, 979	2, 821	----------	3, 369	445
G–30	60	294	745	1, 176	2, 000	2, 745	3, 020	520
G–4	60	542	1, 070	1, 945	2, 833	----------	2, 833	400
Clay X	30	438	1, 017	1, 749	2, 710	----------	2, 710	405
G–35	75	499	1, 030	1, 675	2, 417	----------	2, 694	425
Clay Y	75	546	1, 068	1, 761	2, 330	----------	2, 511	415
China clay	45	344	731	1, 204	1, 763	----------	2, 452	490
G–26	30	467	1, 056	1, 367	2, 422	----------	2, 422	400
G–24	75	351	788	1, 340	2, 000	----------	2, 170	415

Manufacturer C's comments on these tests of aged stock were as follows:

> You will note that in some cases the final tensiles differ slightly from those given in our first report. There are several ways to explain this. First, natural experimental error; second, in some cases we did not have enough stock to cut very satisfactory test pieces and had to make a few tests transversely. [All the results given above were from pieces tested longitudinally.] Third, the aging of the stock for a short time also has some effect on the tests. Although the pieces were not aged long enough to really show any deterioration, there is always a slight stiffening effect in compounded rubber not tested within a day or two after cure. In the case of clay X, the pieces, while tested longitudinally, were not very satisfactory. Stock with this clay was on hand from another batch made up on the same formula, and after aging nine days, gave an ultimate strength, at 45 minutes, cure, of 3,124 pounds at 400 per cent elongation.

RESULTS OF MANUFACTURER D

Formula

Pale crêpe	100
Aniline	3
Sulphur	10
Clay	63=25 volumes.

Batches were cured at 286° F, 40 pounds steam pressure, for 105, 120, 135, and 150 minutes. Tests were made four days after curing and after heat aging for one week at 158° F. dry heat.

Tests four days after curing

Sample	Hardness	Set	Abrasion	Cure	Maximum tensile stress, pounds per square inch	Maximum elongation
G-6	66	0.42	117	120	2,465	590
G-9	68	.38	96	135	2,375	730
G-26	67	.44	109	150	2,275	600
G-24	63	.38	104	150	2,250	610
G-16	66	.43	100	120	2,150	630
G-27	65	.46	107	150	2,110	570

The abrasion is in comparison with a plant standard taken at 100 per cent, which is not a clay stock. The set was taken 30 seconds after breaking the test pieces.

Tests after heat aging one week at 158° F.

Sample	Set	Cure	Maximum tensile stress, pounds per square inch	Maximum elongation
G-6	0. 27	120	1, 985	450
G-26	. 35	120	1, 650	480
G-9	. 25	105	1, 445	400
G-27	. 42	120	1, 415	520
G-24	. 21	150	1, 390	390
G-16	. 21	105	1, 125	350

Manufacturer D's comments were as follows:

Judging from the tests as a whole, G-6 is decidedly superior to the others. It stood above the others to a marked degree in respect to abrasion and tensile, which are of great importance from a rubber man's point of view. Its aging can be considered good. The tests of stretch and set are somewhat of secondary importance, but are normal for a clay in this stock. We believe this clay would be acceptable to the rubber people. The stocks containing G-16, G-24 and G-27 do not heat age as well as expected of a clay stock, and for that reason, these three clays should not be considered for the best grade rubber stocks. The poor aging is concluded from the abnormal drop in tensile and stretch. The six clays mix with rubber in a satisfactory manner.

RESULTS OF MANUFACTURER E

Formula

Smoked sheets	50
Pale crepe	50
Diphenylguanidine	.40
Sulphur	2.50
Zinc oxide	6.00
Clay	38.00

Batches were cured at 286° F., 40 pounds, for 75, 90, and 105 minutes.

Tests by manufacturer E

Sample	Cure	Tensile stresses (pounds per sq. in.) and elongation							
		100	200	300	400	500	600	Maximum tensile stress	Ultimate elongation
G-4	105	100	242	455	780	1, 351	2, 219	2, 770	655
G-28	105	115	256	480	840	1, 436	2, 360	2, 660	630
G-39	90	100	240	455	770	1, 365	2, 205	2, 640	640
G-16	105	142	327	583	1, 010	1, 735	--------	2, 590	590
G-41	105	128	298	540	920	1, 607	--------	2, 130	560
G-40	105	140	313	555	940	1, 605	--------	2, 060	555

Manufacturer E's comments were as follows:

It seems that two different classes of clays are here represented, your samples marked G-4, G-28 and G-39, showing higher tensile and better elongation, but less reinforcing power than samples numbered G-16, G-40 and G-41.

A study of all the results from manufacturer E suggests that the cure had not been carried over a wide enough range to obtain the maximum tensile available as in the table, all the maximum results except one were obtained from the longest cure.

COMPARISON OF CLAYS TESTED

Below is a comparison of results that is based on the reinforcing or stiffening properties of the clays. As pointed out by manufacturer A, however, there is a use for the "softer" clays in certain stocks, and a low ultimate breaking strength does not necessarily mean that the clay would be valueless for use in rubber, but does mean that the clay would be unsuitable for displacing zinc oxide or other reinforcing pigments.

Of the four manufacturers to whom G–6 was submitted, three reported it superior to any of the others, or better than G–1, 4, 7, 8, 9, 15, 16, 24, 26, 27, 30, and 35. G–4 was submitted to three, one reporting it first and the other two second, or superior to G–1, 7, 8, 15, 16, 24, 26, 28, 30, 35, 39, 40, and 41. G–39 was submitted to two, one reporting it first and the other third, or superior to G–16, 28, 30, 35, 37, 40, and 41. G–30 was submitted to two, and was reported second by one, and third by the other (the two above it here being G–4 and G–6), or as better than G–24, 26, 28, 35, and 37. G–35, however, immediately follows it in both lists, and the tensile was reported by the two manufacturers only slightly less. G–9 was tested by only one manufacturer who reported it second. To summarize the results: G–6 stands first, followed by G–4 and G–39; G–9, G–30, and G–35 can be grouped as about equal and follow the first three. The others are of less value, for reinforcing properties, with probably G–7, 15, 28 and 37 showing the most promise of this second group.

Stress-strain curves of the best sample from each series of tests, where full data were received from the manufacturers, are shown in Figure 5. The curve for Manufacturer C is from a test of stock aged 90 days. Unless the different formulas and conditions of test are noted, the curves are hardly comparable.

EFFECT OF GRAIN SIZE

Although some of the results seem at variance with the assumption that of two pigments of the same kind the one with the finer particle size will have the greater reinforcing power, and although not enough tests with any one compound were available to give averages, it is believed that all the plots in Figures 6 and 7 are so nearly of the same character that they bear out this assumption. The letters designating the curves refer to the test by the corresponding manufacturer. Curve C_1 is from values obtained after aging 90 days. Values for average particle size and percentage surface of grains two microns and finer were taken from Table 4 and the "Pounds per sq.

in." are maximum tensile stresses from the results of tests. Some of the points, especially those for G–8 and G–24, are considerably at variance. This may be due to experimental errors in testing the compounds or in determining particle size, or to the sample tested differing in some way from the portion where particle size was determined. The results of E were inconsistent as compared with the others and were not plotted.

The photomicrographs in Plate II (p. 13) illustrate the difference in texture of clays with different particle sizes. *A* is a Georgia sedimentary kaolin with average particle size of about 2.5 microns, whereas *B* is an English china clay with average particle size of about 6 microns. To show a truly representative field is impossible, but the two photomicrographs illustrate the difference.

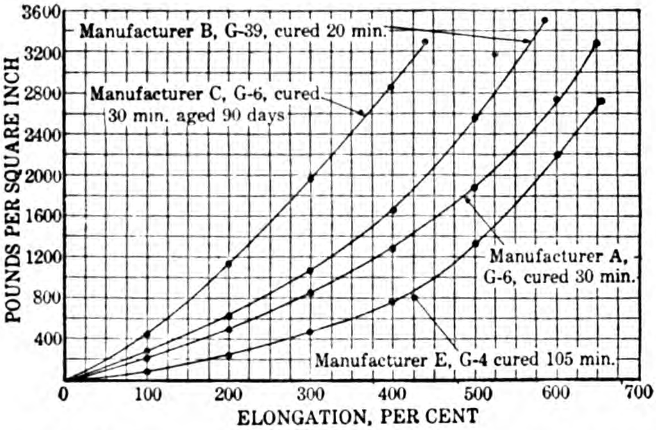

FIGURE 5.—Stress-strain curves, from highest result of each test

ESTIMATED VALUE OF CLAYS NOT TESTED

As all samples were not tested in actual compounding, the tentative classification given below is based on particle size and percentage of finer sizes. Although a compounding test is the final criterion, this classification is intended to indicate which of the untested clays give most promise of good results as reinforcing pigments.

Clays G–31, G–34, G–38, and A–3, A–6, A–7, and A–8 seem worth investigating for reinforcing properties. G–29, G–32, G–33, G–36, G–42, and A–2 and A–9 may be regarded as having possibilities and go in a second group. The remaining clays will probably not show any particular value where reinforcing properties are desired.

USE IN OILCLOTH

Methods of testing clays for oilcloth are not standardized. Different manufacturers employ different methods of determining the properties they consider essential. In general, a clay should be white, free from grit, should slake readily to a smooth cream or slip without lumps, and have a comparatively low oil absorption.

Fifteen samples (G–1, 4, 6, 7, 8, 9, 16, 26, 27, 28, 30, 35, 37, 39, and 40) were sent to each of two manufacturers of oilcloth, coated cloth, and similar products. The results of the tests made and the opinions of the manufacturers are given as received.

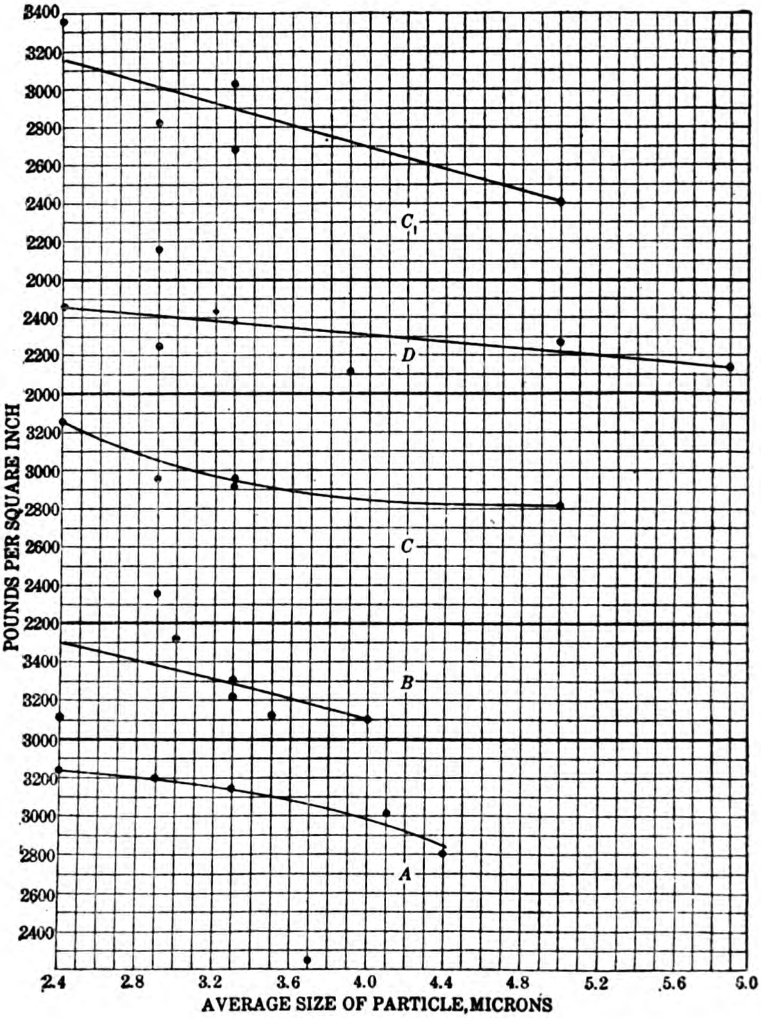

FIGURE 6.—Relation of breaking stress to particle size

REPORT OF MANUFACTURER F

These samples have been compared to the clay which we are using and have found satisfactory. A rejection by our laboratory would not necessarily mean that the clay would be unsatisfactory for some other manufacturers.

Samples No. G–9 and No. G–35 we would consider as being a very good match for the clay that we are now using. All the samples show a satisfactory color.

The following we would reject on account of the fact that they settle too fast from water:

G–4, G–16, G–26, G–27, G–28, G–30, G–39

In case a sample showed an unsatisfactory result in settling test we did not carry out the examination any further.

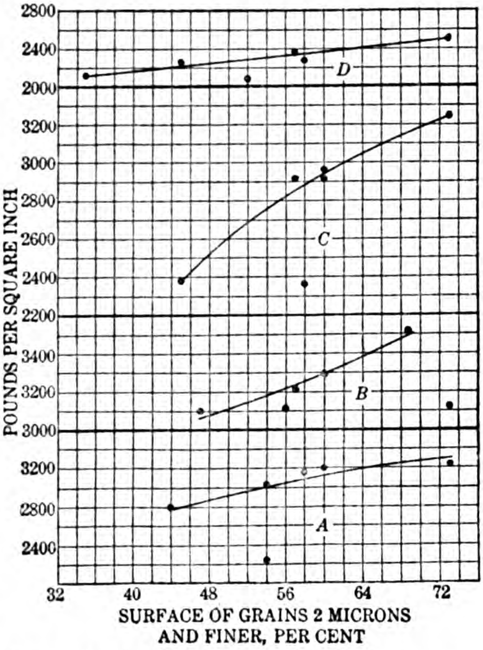

FIGURE 7.—Relation of breaking stress in proportion of fine grains

The following samples, while satisfactory in regard to the settling, show a higher oil absorption than would be satisfactory to us:

G–6, G–7, G–8, G–37, G–40

You will note that these two tests have eliminated all except three of the samples, these three being G–1, G–9, and G–35.

REPORT OF MANUFACTURER G

As per your request we examined them carefully by comparing with clay we are now using which is giving entire satisfaction. We have no doubt that these clays can be used as fillers on cloth.

The structure of all samples was equal to clay now in use, showing a very small amount of coarse, gritty particles.

The water absorption was about the same as clay we are now using. Did not vary enough to make note of.

There are five of the samples with poor color; the remainder would answer where our clay is used. The shades vary; the following list gives an idea of the shades:

Sample	Color	Shade	Sample	Color	Shade
G—1	O. K	Grey.	G—27	O. K	Yellow.
G—4	Good	White.	G—28	do	Do.
G—6	Poor	Brown.	G—30	do	Do.
G—7	O. K	Yellow.	G—35	Good	Brown.
G—8	do	White.	G—37	Poor	Do.
G—9	Poor	Brown.	G—39	do	Do.
G—16	O. K	Grey.	G—40	do	Do.
G—26	Good	White.			

A dry bulk determination was made which indicated that the majority of samples are of finer structure than the clay we are now using.

The below results show the volume in cubic centimeters of 25 grams, after tamping under the same conditions:

	Volume, c. c.
Clay now in use	35
Sample G—1	45
Sample G—4	42. 5
Sample G—6	52
Sample G—7	49. 5
Sample G—8	49
Sample G—9	34
Sample G—16	47
Sample G—26	42. 5
Sample G—27	39
Sample G—28	35
Sample G—30	37
Sample G—35	39
Sample G—37	33
Sample G—39	26
Sample G—40	41

DIFFERENCES OF OPINION

A comparison of the results from the two manufacturers show that their standards and the qualities they stress the most are different. Manufacturer F desires low oil absorption and slow settling properties, and deems color of less importance. Manufacturer G seems to consider color of most importance. In a separate communication he says that a clay for oilcloth should first be nearly white or about the color of raw cotton yarns. It should be of a reasonably fine texture, and should temper easily and uniformly with water and have a soapy feel when rubbed with the fingers. According to his color requirements, a yellow shade is less objectionable than a brown. Manufacturer F is not so strict in color requirements; he includes G–9 among the best although manufacturer G classes its color as " poor."

In view of these conflicting opinions, it would be difficult and unfair to attempt to classify the samples of clays not tested. Any of the samples that show a good color, have a moderate or low oil absorption, and temper easily with water, have possibilities and should be worthy of trial.

USE IN PAINT

No sample was tested for use in paint, as the reliable conclusive test is that of endurance in service for a period of years. The value and use of clays and other nonmetallic pigments in paints has been much discussed and has been covered to some extent by Gardner,[16] Ingalls,[17] and others.[18]

Color is of first importance, not only for a dry clay but for a clay mixed with oil. Many clays that are a good white when dry turn dark when mixed with oil. High covering power is often specified as a requirement, but all clays rank low as compared with the higher priced pigments, and clay is seldom used in such proportion as to make covering power of first importance. Freedom from grit and low oil absorption are important properties. The clay, of course, should not contain free acids or alkalies, even in small amounts. Other things being equal, the finer the grain of a clay, the better it is for paint. A clay should mix readily with oil without causing coagulation.

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[16] Gardner, H. A., Paint technology and tests. New York, 1911, 266 pp.

[17] Ingalls, F. P., Use of silica and other mineral fillers in paint: Rock Products, Feb. 26, 1921, to May 7, 1921.

[18] The Chemical Age (London), China clay in paints: China Clay Trade Review Section, July 21, 1923, p. 11.

To determine the color with oil, samples of the clays were worked up with glycerin on a ground-glass plate, the samples compared with each other, and the clays were classified by comparison with the whitest. Glycerin was used instead of linseed oil because the brownish-yellow hue of the oil tends to obscure the true color of the clay. Those clays that, when mixed with oil, were so dark as to have no possible value in paint were not considered. Some of the samples did not work up satisfactorily but all of these were the darker clays.

Clay G-4 was the whitest; when worked it was a very light cream color. It was taken as a standard for the others and called grade 1. The remaining samples were graded as follows: Grade 2, G-8, G-29, G-30, G-32, G-34, G-36, G-41, A-2; grade 3, G-2, G-16, G-26, G-31, G-33, G-37, and A-9.

None of the samples contained enough grit to render them unsatisfactory for paint.

If the oil absorption, Table 3, is taken in connection with the color when mixed with oil, the clays rank about as follows for use in paint: G-4, A-2, G-29, G-32, G-30, G-8, G-16, G-2, G-37, A-9, G-33, G-26, G-31.

Clays G-34, 36, and 41 were eliminated on account of high oil absorption.

OTHER USES AS FILLERS

The desirable properties that a clay should have for the minor filler uses, as specified by different industries and by individual consumers, are so conflicting that no attempt was made to determine the relative merits of the clays examined. These uses are mainly for coating wall paper, in plaster and plaster products, as filling for textiles and window shades, kalsomine, crayons, toilet and tooth powders, soaps, soft polishing compounds, phonograph records, and matches.

For all these uses it may safely be said that whiteness and freedom from grit are the qualities most desired.

SUMMARY

Any general classification of the samples is difficult, because consumers, even in the same line of industry, differ materially as to the specifications and the qualities desired. Nevertheless, it is believed that an indication of the probable best use of each clay for filler purposes may be of value as a guide to the producer looking for a market and to the consumer in search of suitable material.

The following list indicates what is probably the first and the second best use. For some clays, a third use is suggested. A producer, of course, may find that some other use offers a better market, because competition is less or freight rates are more favorable. No comparison between the samples is considered in this summary, and the relative merits must be determined by reference to the discussion of the particular use. For example, rubber is suggested as third choice for G–36 and first for A–6, and yet G–36 might be superior to A–6 as a filler for rubber.

G–1. Oilcloth, paper.
G–2. Paint, oilcloth.
G–4. Paint, paper, rubber.
G–6. Rubber.
G–7. Paper, rubber.
G–8. Paint, oilcloth, paper.
G–9. Rubber, oilcloth, paper.
G–15. Rubber, paper.
G–16. Oilcloth, paint.
G–17. Probably of little value for filler.
G–22. Probably of little value for filler.
G–24. Probably of little value for filler.
G–26. Paper, oilcloth, paint.
G–27. Oilcloth, paper.
G–28. Oilcloth, rubber.
G–29. Paint, rubber, paper.
G–30. Paper, rubber, paint.
G–31. Paper, rubber.
G–32. Paint, paper, rubber.
G–33. Paper, rubber, paint.
G–34. Paper, rubber, paint.
G–35. Paper, rubber, oilcloth.
G–36. Paint, paper, rubber.
G–37. Paper, rubber.
G–38. Rubber, paper.
G–39. Rubber, paper.
G–40. Paper.
G–41. Paper, oilcloth, rubber.
G–42. Paper, oilcloth.
G–43. Probably of little value for filler.
G–44. Probably of little value for filler.
A–1. Probably of little value for filler.
A–2. Paint, oilcloth.
A–3. Rubber.
A–4. Probably of little value for filler.
A–5. Paper, oilcloth.
A–6. Rubber.
A–7. Rubber.
A–8. Rubber.
A–9. Paint, oilcloth.